WADC TECHNICAL REPORT 53-109
PART 1

THE TENTATIVE TITANIUM-SILVER BINARY SYSTEM

HENRY K. ADENSTEDT
WILLIAM R. FREEMAN, JR., 1ST LT, USAF

MATERIALS LABORATORY

APRIL 1953

WRIGHT AIR DEVELOPMENT CENTER

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THE TENTATIVE TITANIUM-SILVER BINARY SYSTEM

Henry K. Adenstedt
William R. Freeman, Jr., 1st Lt, USAF

Materials Laboratory

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Materials Laboratory
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Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

The binary equilibrium diagrams of titanium and its alloying elements can be considered absolute prerequisites for the understanding of all technical titanium-base alloys.

In the course of the alloy development work, which the Materials Laboratory has been sponsoring for several years at Battelle Memorial Institute, the first, very preliminary knowledge of the phase relationships at the titanium-rich end of such diagrams was obtained. This investigation has also furnished a broader knowledge of the applicability of the different alloying elements for practical alloys.

In view of the aforementioned necessity for a knowledge of the binary equilibrium diagrams, and the paucity of information on this subject in the literature, it was decided to start at an early date, a broader research project on binary diagrams of titanium and the most promising alloying elements. Investigation was started on ten systems, the work being divided among five research institutions. More recently, several new binary and ternary systems have been included in this program.

After the first year of research, a summary report was prepared by each contractor and these reports have been published as Technical Reports. The following list gives a compilation of the contractors, systems investigated, and Technical Report numbers concerned. At the time of publication, some of the projects were not completed, therefore some systems are defined in two reports designated as Parts 1 and 2.

Contractor	Systems Investigated	Report No.
Armour Research Foundation	Ti-Si, Ti-Cb, Ti-Mo Ti-O, Ti-Al, Ti-Fe-Cr	AFTR 6225 WADC TR 52-16
Battelle Memorial Institute	Ti-Mn, Ti-Ta, Ti-W	AFTR 6516, Parts 1 & 2
Massachusetts Institute of Technology	Ti-Cr, Ti-Cu, Ti-Cr-O	AFTR 6595, Parts 1 & 2 WADC TR 52-255
New York University	Ti-Ni	AFTR 6596, Parts 1 & 2
University of Notre Dame	Ti-Fe	AFTR 6597, Parts 1 & 2

This report was prepared by the Materials Laboratory, Directorate of Research, WADC, and was initiated under Research and Development Order No. 615-11, Titanium Metal and Alloys. Lt. W. R. Freeman, Jr., acted as project engineer. Work has not been completed, therefore, results are subject to modification upon completion of the project.

ABSTRACT

Silver is a beta former when alloyed in small amounts with titanium. There is a large range of solubility of silver in alpha titanium and it reaches a maximum of 9 ± 1 wt.% silver at 1560 ± 7°F, at which temperature an eutectoid reaction, $\beta \rightleftharpoons \alpha$ + TiAg, occurs at 17 ± 0.5 wt.% silver. The beta solid solubility increases to 30.5 ± 1 wt.% silver at 1903 ± 5°F.

Contrary to general opinion, the existence of the compound TiAg (69.25 wt.% Ag) has been established. It is formed at 1903 ± 5°F by the following peritectic reaction: β + Liq. $\rightleftharpoons$ TiAg. The composition limits of the compound have, as yet, not been determined; however, the compound field appears to be narrow from preliminary observations.

Titanium is soluble in silver in an amount of less than 0.5 wt.% as two phases are present in 99.5 wt.% silver as-cast alloys.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. E. SORTE
Colonel, USAF
Chief, Materials Laboratory
Directorate of Research

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PURPOSE

During an evaluation of materials for the brazing of titanium, it was found that silver was one of the few metals that produced a ductile brazed joint. With the evolution of silver as a brazing constituent, interest was aroused in the titanium-silver binary system because of the apparent ductility of the joints. Such ductility led to the belief that no compounds were present in this system. In order to better understand this system, work was undertaken to establish the binary diagram.

LITERATURE SURVEY

At the outset of this investigation, there was a negligible amount of information available on this system. Limited work was accomplished by Battelle Memorial Institute (1) while making a survey of attractive alloying additions to titanium. During the course of the present investigation, Armour Research Foundation, under sponsorship of the Watertown Arsenal, Contract No. DA-11-022-ORD-288, reported on their observations of the compound, TiAg (2). Armour reported the compound, TiAg, as having a face-centered tetragonal structure with a c/a value of 0.993. Studies were conducted using both iodide and Process A titanium and high purity silver.

ALLOY PREPARATION

a. Material. Iodide titanium (New Jersey Zinc Company - 99.9+%) and high purity silver (99.9+%) were used in the investigations up to 25 wt.% silver. Above this range, Dupont Process A titanium was substituted for iodide titanium.

b. Melting and Preparation of Alloys. The major portion of the melting and alloy preparation was conducted by New York University, Contract AF 33(616)-22, under the sponsorship of the Materials Laboratory. A description of melting techniques may be found in a paper entitled "Titanium-Nickel Phase Diagram," by Nielsen and Margolin (3).

Alloys requested by the investigators were carefully weighed and melted in an arc furnace several times as indicated in Table I. Specimens were then sectioned for metallographic analysis and rolled when possible.

An argon atmosphere was found to be superior to helium at the titanium-rich end of the diagram since silver losses were less with such an atmosphere. With increasing silver content, it became more and more difficult to obtain homogeneous melts using argon, therefore, helium was substituted, which is known to create a much hotter arc. A substantial increase in homogeneity of the structure was obtained in this way.

c. Weight Loss Due to Melting. In the range of 0-30 wt.% silver, the losses of alloying additions were large due to the vapor pressure of silver at the melting temperature of titanium. As the silver content increased, the loss of silver decreased since the temperature required for melting was decreased continually.

d. Chemical Analyses. For alloys containing less than 20 wt.% silver, weigh out an alloy sample containing approximately 100-200 mg. of silver into a 250 ml. beaker. Add 5-10 ml of 1:1 HNO_3, dilute with 10-20 ml water, and dissolve by adding HF; heat until the specimen is in solution. Cool to room temperature, dilute in water to 200 ml, add 5 ml. of saturated ferric alum, and titrate with 0.1 N potassium thiocyanate until a permanent red-brown color appears.

For alloys in the range 20-100 wt.% silver, the following procedure is employed. Dissolve the weighed sample of alloy in a 60 ml. Pt crucible using approximately 10 ml. HF and HNO_3 in equal amounts added drop by drop until the sample is completely dissolved and 10 ml have been added. Add 25 ml hot water and transfer to a 400 ml beaker, dilute the solution to 300 ml and heat to boiling using an aluminum evaporator. While the solution is boiling, add 3 ml 1N HCl, drop by drop. Boil the solution until clear and then remove from the heat. Cool in cold water and filter using a medium fritted glass (weighed) crucible and wash with water containing 1 ml 1N HCl per 100 ml volume. Dry at 160°F for one hour and weigh.

e. Alloy Peculiarities. Alloys above 30 wt.% silver in content were very difficult to melt with any degree of homogeneity due to the wide melting range existing above that composition limit. Upon cooling, the large difference between the density of the solid beta and the liquid silver caused the beta particles to tend to float. The high conductivity of the silver made it difficult to melt specimens completely, therefore numerous meltings were required. The use of helium instead of argon as an approach to the solution of this problem has already been discussed.

Difficulty was also experienced when cold reduction of any sort was attempted on alloys in the range of 20-90 wt.% silver in the as-cast condition. Hot rolling at 950°C under atmospheric conditions was

employed on alloys up to 40 wt.% silver with little difficulty. Surface contamination was ground off in all cases. Attempts were made to hot roll the as-cast ingots in the 40-90 wt.% silver region, but no success was obtained. After annealing (1700°F), specimens in the region of the compound (69 wt.% Ag) could be cold worked in cases where the alloy was homogeneous. Observations from microhardness testing indicated that all phases present were relatively soft, the compound being softer (130 Vickers) than either alpha or beta titanium solid solution. Cold rolling was accomplished successfully in the range 90-100 wt.% silver.

HEAT TREATMENT

As mentioned above, alloys were either hot or cold rolled whenever possible to remove the cast structure before heat treatment. One-fourth inch cubes were sealed in Vicor tubing under a vacuum of 10^{-5} mm Hg prior to heating. All specimens and tubes were degassed by heating in a vacuum before the sealing operation. Atmospheres of helium were attempted in the capsule, but little improvement in silver losses was noticed. Vicor was not employed at temperatures above 1950°F, and temperatures above 1900°F were for short periods only. After heat treatment, the sealed specimens were rapidly placed under water and the capsule shattered in order to obtain rapid quenching conditions.

For incipient melting determinations and high-temperature heat treatment, a controlled-atmosphere resistance furnace was used. This furnace is described in Figure 16, and only the furnace proper is shown. The heating element consists of a thin molybdenum sheet rolled to form a cylinder 12" long and 1-1/2" in diameter and held in shape by molybdenum clips. The element is held in position by two brass bushings which also serve as conductors. Optical measurements may be made on the specimen through a slot in the tube lined up with the sight port.

Controlled voltage is supplied to a 10-kva transformer. The transformer is connected to the furnace and a current of 0 to 1000 amp at 10 volts maximum may be applied to the heating element.

The vacuum system consists of a mechanical pump plus an oil diffusion pump capable of attaining a vacuum of 10^{-4} mm of Hg. Pressure is measured by a McLeod gauge initially and finally by a Philips gauge usable to 10^{-5} mm of Hg pressure.

Helium is used for a protective atmosphere after a suitable vacuum is obtained. The gas is first passed through a cold trap to remove any water vapor present. A bubbler on the gas exit prevents any leakage of atmosphere into the furnace.

For the purpose of incipient melting, specimens are cut to one-fourth inch cubes and suspended in the heating element by a tungsten wire. In order to approach black-body conditions for temperature measurements, a small diameter hole is drilled deep into the side of the specimen facing the sight port.

When melting starts, it is noticed by the corners beginning to round off and the hole starts to fill with the melt. In this particular system, melting of higher-silver (35-60 wt.% Ag) alloys, difficulty in accurately observing the initiation of melting was observed due to the relative densities of titanium and silver. A substantial weight percentage of liquid (silver-rich) phase must be present to show appreciable volumes. The remaining solid beta (rich in titanium) is in large volumes and the specimen does not change its shape with the initial appearance of the liquid phase.

In order to check suspected discrepancies in the incipient melting determinations, specimens were wired together using molybdenum wire and suspended in the resistance furnace for short time heat treatment at temperatures above 1900°F. Subsequent to heat treatment the specimens were cooled as rapidly as possible by increasing the flow of cold helium past the specimens after the furnace power was cut. Specimens were then sectioned for metallographic examination to determine the presence or absence of a liquid phase formed at heat treatment temperatures.

METALLOGRAPHY

a. Preparation. Specimens to be examined were first sectioned to avoid incorrect observation of surface conditions affected by the loss of silver during heat treatment. Two methods of polishing were employed during the investigation of this system. Electrolytic polishing was useful in the composition range up to 30 wt.% silver, depending upon prior heat treatment. Above this range, however, the electrolytic process severely attacked the TiAg phase making optical analysis difficult. The equipment used for this procedure was homemade and a description of it and the normal operating procedures may be found in a paper by Adenstedt, Raymer, and Pequignot (4).

The second type of polishing employed mechanical means, the initial preparation being the mounting in bakelite and then the grinding using the following grades of silicon carbide papers wetted with water: 180, 280, 320, and 600. Intermediate polishing was accomplished using 6 micron diamond paste dispersed on aircraft silk by filtered kerosene. Final polishing was made using Linde B-5125 on Microcloth.

Three etchants were primarily used on this system and the appropriate description may be found under each photomicrograph. A more detailed description of the chromic-sulfuric acid etch is worthy of mention at this point. A concentrated stock solution is made by the following formula and is diluted for use by adding nine parts of water to each part of etchant:

100 ml sat. sol'n. of Potassium Dichromate in Water

2 ml sat. sol'n. of Sodium Chloride in Water

10 ml of conc. Sulfuric Acid (added slowly)

Difficulty in etching specimens near the compound region and in the two phase regions above the compound composition made it necessary to vary etching techniques. Small amounts of silver rich phases were readily attacked by normal titanium etchants, and small amounts of compound phases present in a silver matrix were readily attacked by silver etchants. Several etchants were used with little success, and eventually the chromic-sulfuric mixture was used with varying intensity depending upon which phase of the structure was of interest. The compound can be readily observed by means of polarized light.

b. Results. The tentative Titanium-Silver Phase Diagram is presented in Figure 1. Initially, heat treatments were conducted above and below the alpha-beta transformation temperature to determine the type of equilibrium at the titanium-rich end of the diagram. It was found that the transformation temperature was moderately depressed with increasing silver content. The eutectoid reaction, $\beta \rightleftharpoons \alpha +$ TiAg, is located at 1560 ± 7°F and 17 ± 0.5 wt.% silver. The maximum solubility of silver in alpha titanium is 9 ± 1 wt.% silver at the eutectoid temperature decreasing to about 5 wt.% silver at lower temperatures. Figures 2 and 3 show the alpha solid-solution structure at 5 and 8.4 wt.% silver respectively. At 1533°F, the transition from all alpha solid-solution to alpha solid solution plus TiAg may be observed by comparing Figures 3 and 4 which are 0.5 wt.% silver apart. At somewhat higher temperatures, the effect of increasing silver content may be seen in Figures 5, 6, and 7.

The "horizontal" line at the eutectoid temperature (1560 ± 7°F) has presented a peculiar problem. As may be seen in Figure 1, heat treatments of varying compositions (10-20 wt.% Ag) at the same temperature and time give evidence of being above and below this line depending on the composition. This phenomenon appeared in all treatments of these alloy compositions and in the temperature range of 1553 to 1566°F. Two theories are brought forth to attempt an explanation.

First, there may have been some oxygen absorbed in the silver which was released during the production of the alloys. Since oxygen raises the transformation temperature of alpha titanium, increasing percentages of silver may serve to increase the eutectoid transformation temperature. Another possibility is that with lower percentages of silver, longer periods of heat treatment may be required. (i.e. 7.65 wt.% Ag, H.T. at 1560°F, 115 hrs, W.Q. showed alpha titanium + transformed beta, while 8.4 wt.% Ag, H.T. at 1533°F, 133 hrs, W. Q. showed all alpha titanium - Figure 3.)

Maximum silver solid solubility in beta titanium is reached at 30.5 ± 1 wt.% silver and 1903 ± 5°F. As the temperature increases, the solubility decreases to 0 wt.% silver at 3140°F, the melting point of titanium. Figure 8 shows the liquid phase as it makes its appearance at 2600°F (23.8 wt.% Ag). Specimens of compositions up to 60 wt.% silver were suspended and heated until melting was in evidence. As the silver content increased, it was noticed that all specimens apparently started to melt very close to 2600°F until approximately 60 wt.% silver was reached. Initially, it was suspected that this region was approximately the peritectic transformation temperature, but further study proved that such was not the case. This phenomenon indicates the shape of the beta plus liquid region in that there is a sharp increase in the percentage of liquid present in the neighborhood of 2600°F.

The peritectic reaction β + Liq. $\rightleftharpoons$ TiAg takes place at 1903 ± 5°F and approximately 69 wt.% silver. Figures 9-12 show typical structures of the as-cast condition and below, at, and above this transformation temperature.

The structure of the compound may be readily observed by means of polarized light as in Figure 13. The TiAg changes its appearance under such conditions when the specimen is rotated. The retained beta, however, remains unchanged (black) in appearance during rotation.

With increasing silver content, supression of the beta transformation usually observed upon quenching is not found in this system. In only one case was a specimen quenched from the beta region with resulting retained beta present; the transformation to alpha could be seen starting at the grain boundaries. Beta quenched from the beta plus liquid region was always transformed throughout the entire range. When quenched from the beta plus TiAg-field it was sometimes possible to retain the beta as can be seen in Figure 13.

Specimens heat treated at 2000°F and 2600°F indicate that the slope of the beta boundary is quite steep in that at 1900°F it lies at 30.5 ± 1 wt.% silver and decreases to 23.5 wt.% silver at 2600°F. Figure 8 shows the appearance of the liquid phase from the beta upon heating. At higher temperatures and lower compositions, the incipient melting data are generally considered accurate within ± 25°F.

Less than 1% Ti solubility is present in silver up to the melting point. The transformation TiAg + L $\rightleftharpoons$ TiAg + Ag occurs very close to the melting point of silver; the temperature of this transformation has not been accurately determined. Microexamination of the as-cast 99.75 wt.% silver indicates that the upper limit of the beta plus liquid phase is at 99.5 ± 0.5 wt.% Ag. Figures 14 and 15 depict the two phase structure TiAg plus Ag, in the as-cast condition and after heat treatment just below the melting point of silver respectively.

X-RAY INVESTIGATIONS

Observations on the compound phase have been completed and reported in a paper by Van Thyne, Rostoker, and Kessler (2). This work has been checked and used for identifying the presence of the compound in questioned microstructures.

TiAg has a structure similar to that of AuCu, however, the axial lattice ratio is less than unity. The dimensions of the unit cell are given as follows:

$a = 4.096$ Å $\qquad c = 4.069$ Å $\qquad c/a = 0.993$

The calculated and observed d values may be found in the aforementioned paper.

FUTURE PLANS

Work is in progress at the present time to complete the details of the titanium-rich end of the system. Specimens will be heat treated to further check the region of 95-100 wt.% silver. The limits of the compound field will be definitely established as soon as sufficient alloys are received. X-ray data on the titanium-rich end of the system will be completed.

The completed study will be issued as Part 2 of this report and will be available soon after the completion of the work.

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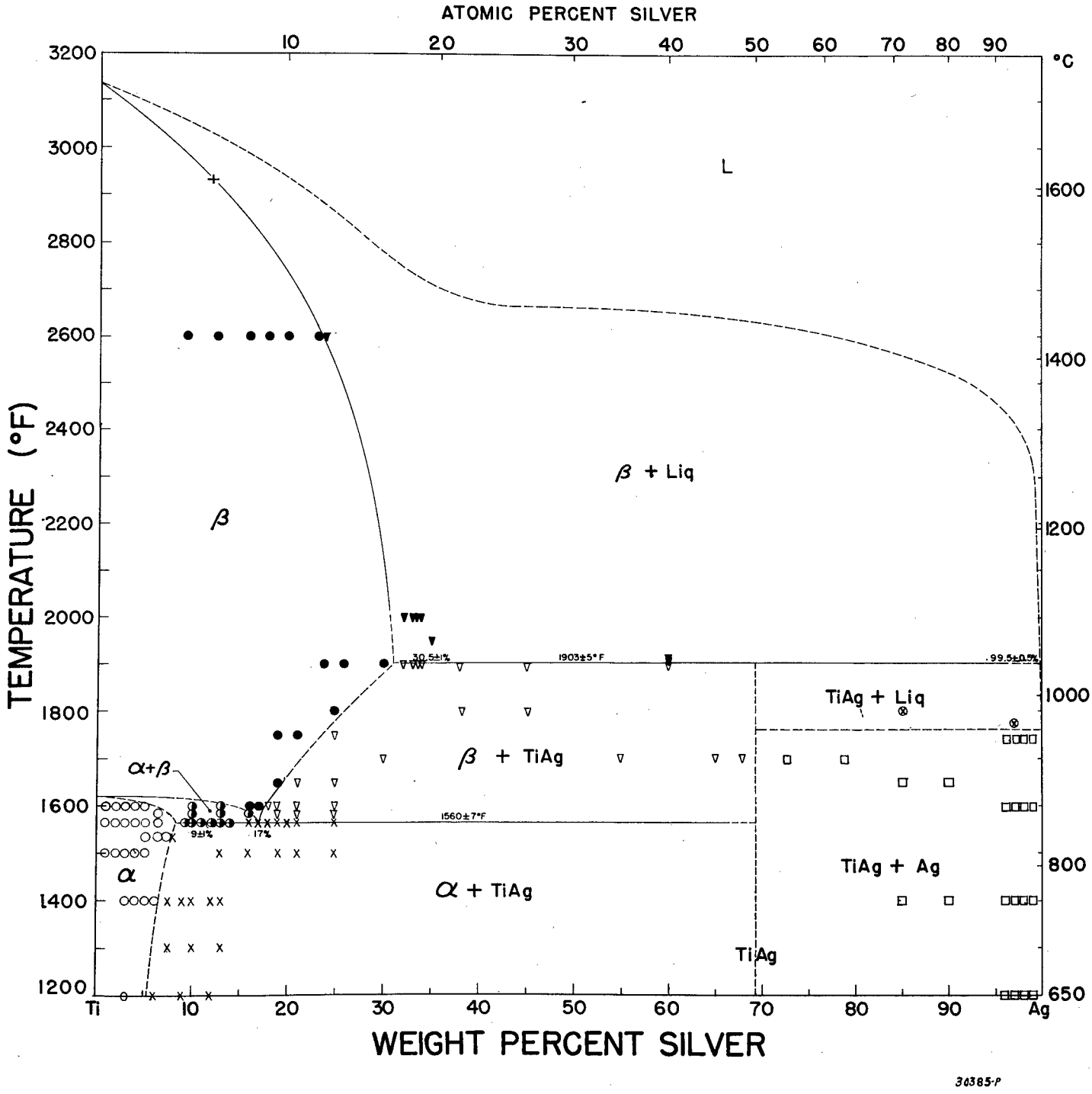
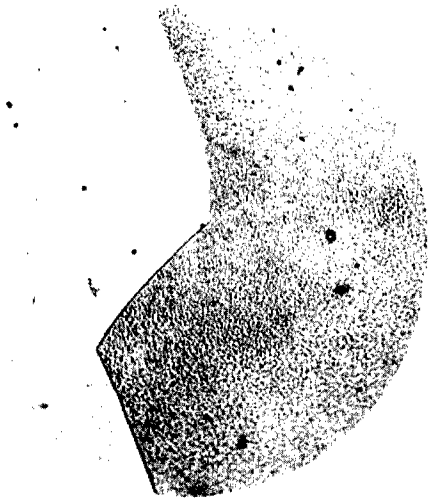


Figure 1.- Tentative Titanium-Silver Phase Diagram

Magn. 100 Etch. 5HF, 95H_2O

Figure 2.- 5 wt.% Silver - 95 wt.% Titanium (Iodide)
Heat Treated at 1500°F and Water Quenched
All Alpha Titanium

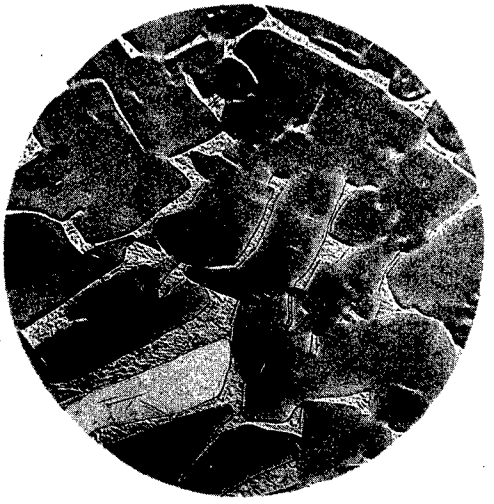


Magn. 500 Etch. 20HF, 20 HNO_3, 60H_2O

Figure 3.- 8.4 wt.% Silver - 91.6 wt.% Titanium (Iodide)
Heat Treated at 1533°F and Water Quenched
All Alpha Titanium (Possible Trace of TiAg)
Grain Orientation Affects Etching Characteristics

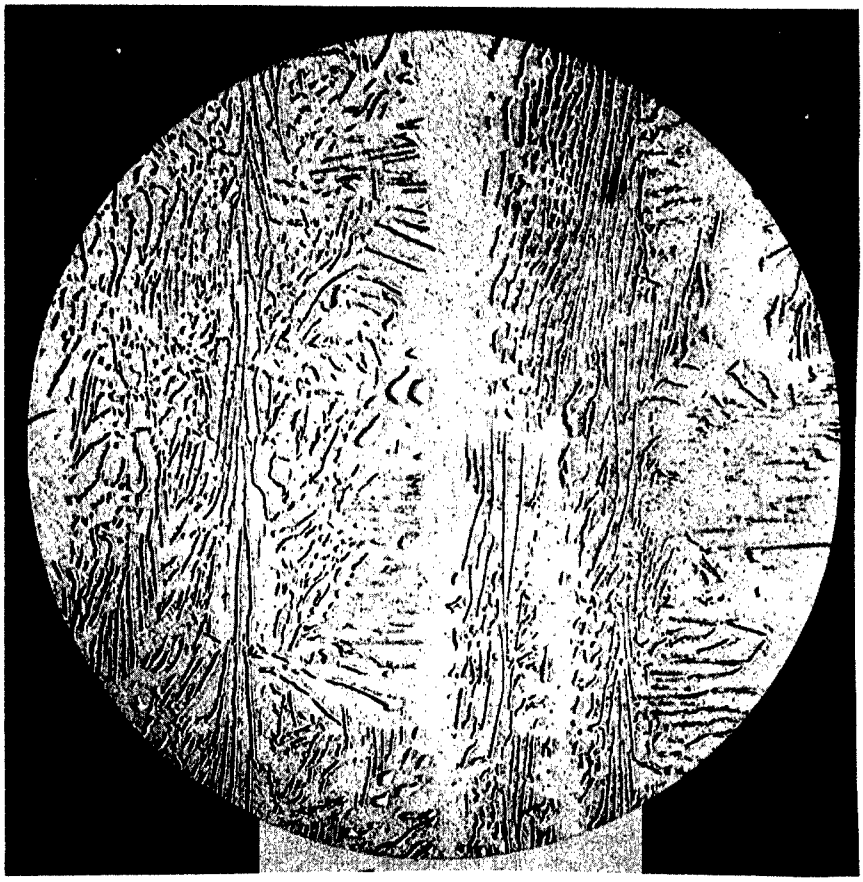
Magn. 300 Etch. 20HF, 20HNO_3, 60 Glycerine

Figure 4.- 8.9 wt.% Silver - 91.1 wt.% Titanium (Iodide)
Heat Treated at 1533°F and Water Quenched
Matrix of Alpha Titanium with Islands of TiAg



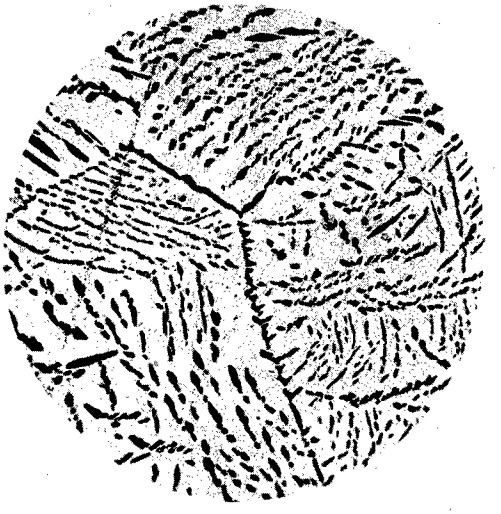
Magn. 500 Etch. 3HF, 3HNO_3, 94H_2O

Figure 5.- 12 wt.% Silver - 88 wt.% Titanium (Iodide)
Heat Treated at 1553°F and Water Quenched
Primary Alpha Titanium plus Transformed Beta
formed by cooling from the Beta Region



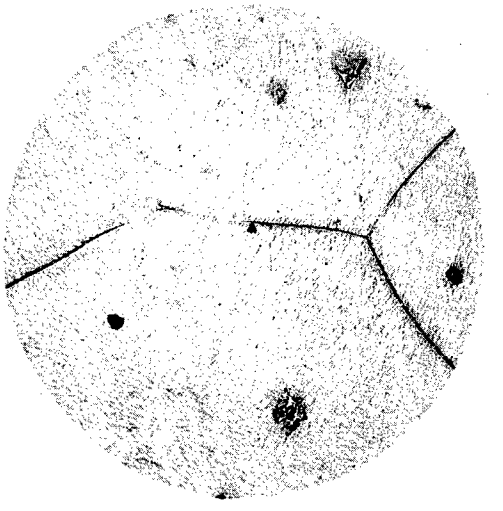
Magn. 1000 Etch. 20HF, 20HNO_3, 60 Glycerine

Figure 6.- 17 wt.% Silver - 83 wt.% Titanium (Iodide)
Heat Treated at 1544°F and Water Quenched
Matrix of Alpha with Platelets of TiAg (Pearlite)



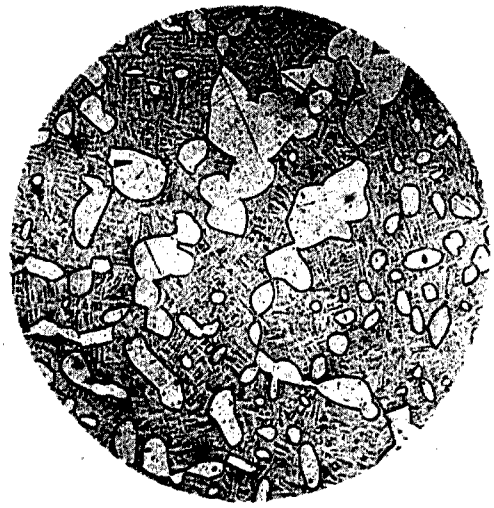
Magn. 100 Etch. 3HF, $3HNO_3$, $94H_2O$

Figure 7.- 20 wt.% Silver - 80 wt.% Titanium (Iodide)
Heat Treated at 1566°F and Water Quenched
Matrix of Beta plus Network and Widmanstätten
Pattern of primary TiAg



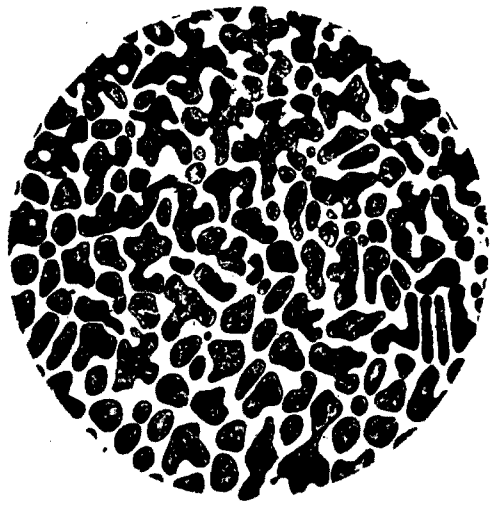
Magn. 100 Etch. 20HF, $20HNO_3$, 40 Glycerine

Figure 8.- 23.8 wt.% Silver - 76.2 wt.% Titanium (Sponge)
Heat Treated at 2600°F, and Helium cooled
Matrix of Transformed Beta plus Ag (liquid) at
grain boundaries and within Beta Grains



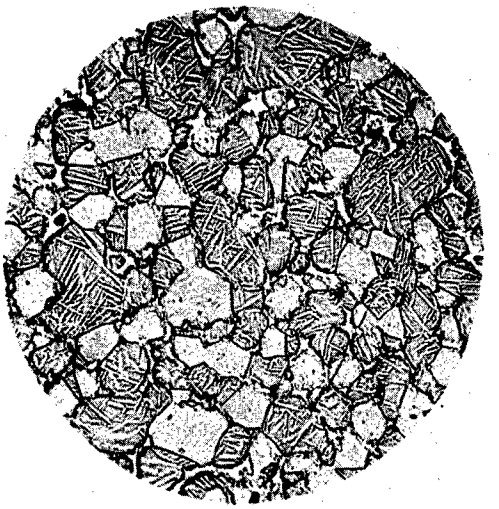
Magn. 500 Etch. 3HF, $3HNO_3$, $94H_2O$

Figure 9.- 40 wt.% Silver - 60 wt.% Titanium (Sponge)
Heat Treated at 1900°F and Water Quenched
Matrix of Transformed Beta plus Islands of TiAg



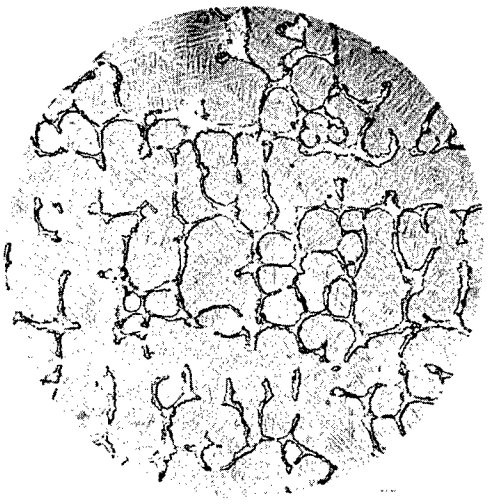
Magn. 500 Etch. 3HF, $3HNO_3$, $94H_2O$

Figure 10.- 60 wt.% Silver - 40 wt.% Titanium (Sponge)
As Cast
Matrix of Silver (liquid) plus Transformed Beta



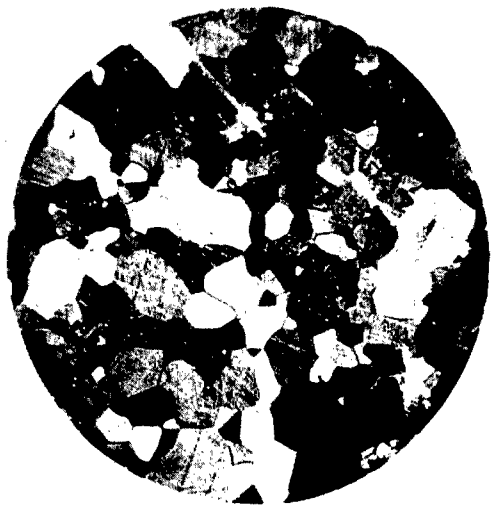
Magn. 500 Etch. 20HF, 20HNO_3, 60 Glycerine

Figure 11.- 60 wt.% Silver - 40 wt.% Titanium (Sponge)
Heat Treated at 1905°F and Water Quenched
Transformed Beta plus TiAg (grey) with
evidence of melting (liquid Ag - white)



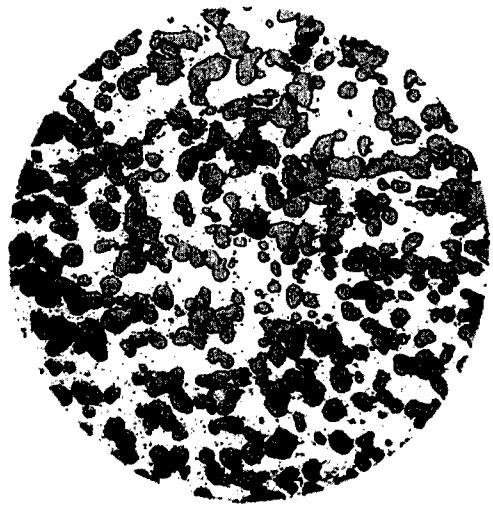
Magn. 500 Etch. 3HF, 3HNO_3, 94H_2O

Figure 12.- 60 wt.% Silver - 40 wt.% Titanium (Sponge)
Heat Treated at 1909°F and Water Quenched
Transformed Beta plus network of Ag (liquid)



Magn. 500 Etch. 3HF, $3HNO_3$, 94 H_2O
Polarized Light

Figure 13.- 60 wt.% Silver - 40 wt.% Titanium (Sponge)
Heat Treated at 1650°F and Water Quenched
TiAg plus small amounts of Retained Beta (Black)



Magn. 500 Etch. $K_2Cr_2O_7$, NaCl, H_2SO_4

Figure 14.- 91 wt.% Silver - 9 wt.% Titanium (Sponge)
As Cast
Matrix of Silver plus Islands of TiAg

Magn. 500 Etch. $K_2Cr_2O_7$ NaCl, H_2SO_4

Figure 15.- 99 wt.% Silver - 1 wt.% Titanium (Sponge)
Heat Treated at 1740°F and Water Quenched
Matrix of Silver plus Islands of TiAg
Deep etched to show Silver Grain Boundaries

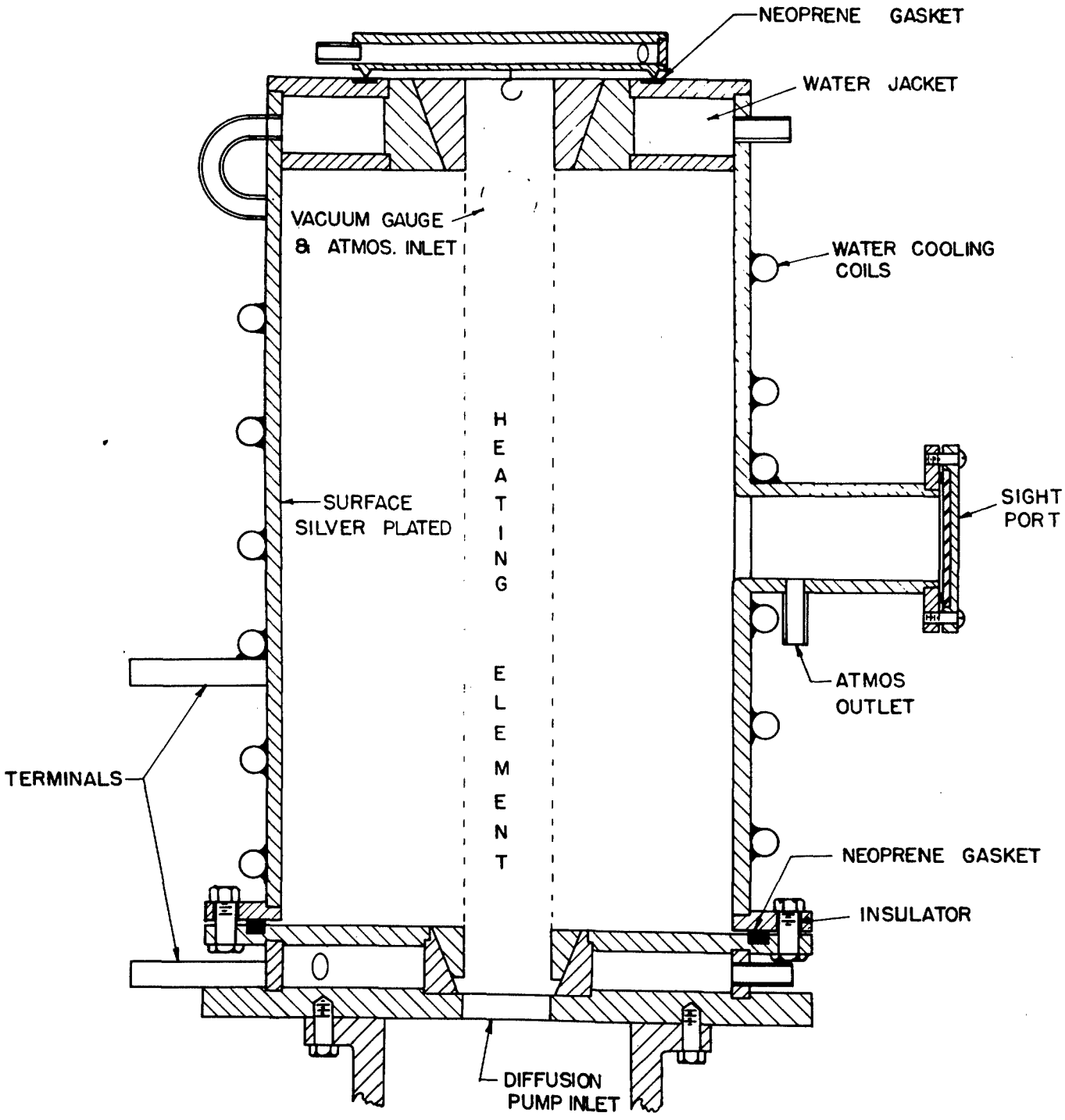


Figure 16.- Diagram of Resistance Furnace

TABLE I

MELTING DATA OF ALLOYS USED IN THE INVESTIGATION OF THE TITANIUM-SILVER SYSTEM

Nominal Wt.% Ag (Plus Additions for Losses)	Wt.% Ag After Melting	Melting Procedure	Rolling Data
1 (Iodide)	--	--	Cold
2 (Iodide)	--	--	Cold
3 (Iodide)	--	--	Cold
4 (Iodide)	--	--	Cold
5 (Iodide)	--	--	Cold
8 + 2 (Iodide)	6.06	250a., 4-30", Argon	950°C
8 + 2.5 (Iodide)	7.6	275a., 4-30", Argon	950°C
9 + 2 (Iodide)	8.74	250a., 4-30", Argon	950°C
10 + 2 (Iodide)	9.41	250a., 4-30", Argon	950°C
11 + 2.5 (Iodide)	10.84	250a., 4-30", Argon	950°C
12 + 3 (Iodide)	12.12	250a., 4-30", Argon	950°C
13 + 3 (Iodide)	12.56	250a., 4-30", Argon	950°C
14 + 3 (Iodide)	13.99	250a., 4-30", Argon	950°C
15 (Process A)	12.2	--	Cold
16 + 4 (Iodide)	17.26	250a., 4-30", Argon	950°C
16 + 3 (Iodide)	15.94	250a., 4-30", Argon	950°C
17 + 3 (Iodide)	13.93	250a., 4-30", Argon+ 250a., 1-30", Helium	950°C
18 + 5 (Iodide)	20.58	250a., 4-30", Argon	950°C
18 + 3 (Iodide)	18.2	275a., 4-30", Argon	950°C

TABLE I (cont.)

Nominal Wt.% Ag (Plus Additions for Losses)	Wt.% Ag After Melting	Melting Procedure	Rolling Data
19 + 5 (Iodide)	13.35	250a., 4-30", Argon+ 250a., 2-30", Helium	950°C
19 + 3.5 (Iodide)	19.36	250a., 4-30", Argon	950°C
20 + 5 (Iodide)	20.19	250a., 4-30", Argon	950°C
24 + 3.2 (Iodide)	24.3	275a., 4-30", Argon	950°C
24 + 5 (Iodide)	25.31	250a., 4-30", Argon	950°C
25 (Process A)	22.1	—	—
28 + 5 (Iodide)	29.75	250a., 4-30", Argon	950°C
32 + 3 (Process A)	31.1	275a., 5-30", Argon	950°C
33 + 3 (Process A)	32.07	275a., 5-30", Argon	950°C
34 + 3 (Process A)	33.41	275a., 5-30", Argon	950°C
34 + 3 (Process A)	33.9	275a., 10-30", Argon	950°C
35 + 3 (Process A)	34.8	275a., 10-30", Argon	950°C
38 + 3 (Process A)	39.91	275a., 5-30", Argon	950°C
40 + 3 (Process A)	39.58	275a., 5-30", Argon	950°C
40 + 3 (Process A)	21.4	250a., 4-30", Helium	950°C
60 + 2 (Process A)	--	250a., 5-10", Helium	--
65 + 2 (Process A)	64.19	300a., 10-10", Argon	--
66 + 2 (Process A)	64.09	300a., 10-10", Argon	--
70 + (Process A)	69.5	300a., 5-5", Argon	--
71 + 3 (Process A)	72.2	250a., 5-10", Helium	--
73 + 2 (Process A)	71.4	250a., 4-15", Helium	--
75 + 2 (Process A)	74.5	250a., 10-10", Argon+ 250a., 4-15", Helium	—

TABLE I (cont.)

Nominal Wt.% Ag (Plus Additions for Losses)	Wt.% Ag After Melting	Melting Procedure	Rolling Data
80 + 0.5 (Process A)	20.19	325a., 5-15", Argon	--
35 + 0.5 (Process A)	36.24	324a., 5-15", Argon	--
90 (Process A)	90.	350a., 5-10", Helium+ 425a., 5-15", Helium	--
90 (Process A)	88.3	300a., 5-10", Argon+ 350a., 10-10", Argon+ 425a., 5-15", Helium	--
91 (Process A)	90.3	375a., 5-15", Argon+ 350a., 5-15", Helium	--
91 (Process A)	90.3	350a., 5-10", Argon+ 425a., 10-15", Helium	--
92 (Process A)	91.7	350a., 5-10", Helium+ 425a., 5-15", Helium	Cold
93 (Process A)	92.	375a., 5-15", Argon+ 350a., 5-15", Argon+ 425a., 10-15", Helium	--
93 (Process A)	93.0	350a., 5-10", Helium+ 425a., 10-15", Helium	--
94 (Process A)	93.1	350a., 5-10", Helium+ 425a., 10-15", Helium	--
94 (Process A)	93.5	375a., 5-15", Argon+ 350a., 5-15", Helium+ 425a., 10-15", Helium	--
95 (Process A)	94.2	300a., 5-10", Argon+ 350a., 5-10", Argon+ 375a., 4-15", Argon+ 425a., 10-15", Helium	--
95 (Process A)	94.4	350a., 5-10", Helium+ 425a., 10-15", Helium	--
96 (Process A)	95.99	375a., 5-15", Argon	Cold

TABLE I (cont.)

Nominal wt.% Ag (Plus Additions for Losses)	Wt.% Ag After Melting	Melting Procedure	Rolling Data
97 (Process A)	96.99	375a., 5-15", Argon	Cold
98 (Process A)	97.99	375a., 5-15", Argon	Cold
99 (Process A)	98.99	375a., 5-15", Argon	Cold
99.25 (Process A)	99.12	400a., 10-15", Helium+ 425a., 10-15", Helium	--
99.5 (Process A)	99.36	400a., 10-15", Helium+ 425a., 10-15", Helium	--
99.75 (Process A)	99.7	400a., 10-15", Helium+ 425a., 5-15", Helium	--

TABLE II

WET CHEMICAL ANALYSES OF SPECIMENS
AFTER HEAT TREATMENT

Intended Composition (Wt% Ag)	Heat Treatment Temperature (°F)	Time at Temperature (Hrs)	Analysis (Wt % Ag)
40	1800	Hot Rolled	39.4
40	2600	Incipient Melting	38.1
15	2930	" "	11.0
68	2300	" "	66.7
25	1800	5	24.5
60	2600	Incipient Melting	56.5
35	2200	1/12	31.5
48	2590	Incipient Melting	46.5
98	1778	" "	97.2
8	1405	100	6.32
10	"	"	9.03
13	"	"	11.85
35	1950	6	34.9
67.6	1700	24	69.7
75.6	1700	24	66.7
70	1700	750	51.5
31.1	2000	1/12	33.18
24.3	2600	1/12	23.11
26	2600	1/12	23.88
30	1905	1/2	29.26
31.1	1905	1/2	32.93
32	1905	1/2	32.13
7.8	1560	41	6.41
6	1556	115	7.65
7.6	1556	115	7.65
8.7	1538	188	8.41
9.4	1538	188	8.86